Australian Government
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DSTO

Validation of an Upgraded Vibration Measurement System for RAAF F404 Engine Test Cells

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ABSTRACT

Ground testing of the F404 engines of the F/A-18 Hornet at RAAF Williamtown and Tindal, essential to the continued safe operation of the aircraft, has been limited in its effectiveness by outdated test equipment. An upgraded vibration measurement system purchased by TFSPO will enable both test stands to to reliably and effectively implement the engine work package procedures, and identify faults. This report details the integration of the hardware components, and the testing and calibration of the system pre and post installation. Laboratory tests and installed comparisons with the existing system indicate that the new equipment is functioning correctly.

RELEASE LIMITATION

Approved for public release

AQ F04-09-0830

Published by

DSTO Platforms Sciences Laboratory
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Fishermans Bend, Victoria 3207 Australia

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AR-012-991
December 2003

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Executive Summary

Ground testing of the F404 engines of the F/A-18 Hornet at RAAF Williamtown and Tindal, essential to the continued safe operation of the aircraft, has been limited in its effectiveness by outdated test equipment. The vibration measurement systems at both locations have been upgraded with support from DSTO. Features of the upgraded system that will enable more accurate results in reduced time are new robust transducers, computer controlled tracking filters and a display that incorporates alarm level information. The new vibration transducers are of a piezoelectric type now being introduced throughout the ADF, minimising the risk of disruption to tests due to routine sensor calibration, or failure.

Replacement of the manually operated tunable filter with digital tracking filters has eliminated the need for a manual process for measuring vibration levels at the engine shaft rotation speeds. This feature of the new system improves the accuracy of these measurements by taking a speed reference directly from the engine tachometers, and has the potential to reduce engine test times. In addition, engine fault diagnosis procedures will be more readily implemented.

The user interface was designed with the aim of reproducing the capability of the current system, to minimise the requirement for retraining current operators. It is anticipated that an upgrade of all test cell systems will take place in the near future, and that the hardware components of this vibration measurement system will be incorporated.

Testing performed in the laboratory prior to installation verified the accuracy of the system against a NATA accredited standard. Comparison of the new system, as installed, with the existing system, were made using measurements of an engine in the test cell. These comparisons indicate that the upgrade is functioning correctly and can be accepted for operation.

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Mr Marsden graduated from RMIT in 1998 with a Bachelor of Aerospace Engineering degree with first class honours. Joining DSTO in 1998, he has worked on rotation in areas of research including engine performance, and durability and damage tolerance. Currently working in the field of machine dynamics, he has been involved in dynamic modelling of various aspects of aircraft propulsion systems.

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Contents

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1. Introduction

The RAAF operates two test stands for running the F404 engine and passing these engines as serviceable for use in F/A - 18 aircraft. One of these test facilities is located at RAAF base Williamtown, the other at RAAF base Tindal.

On the test stand, vibration measurements are taken at three locations on the engine casing; the front-frame, mid-frame and rear mount ring. The mid-frame transducer is an accelerometer permanently mounted on the engine. This transducer supplies information to the Inflight Engine Condition Monitoring System (IECMS). The front and rear transducers are mounted only during test in the Mobile Engine Test Stand (METS). The pre-existing transducers on the front-frame and mount-ring were of a velocity type. These contained delicate moving components susceptible to damage. Difficulties in maintaining the serviceability of this equipment led the TFSPO to purchase an upgrade. It is anticipated that in the near future these test stands will undergo a further upgrade to a fully digital system for monitoring of all engine test parameters, and that the hardware components of this vibration system upgrade will be integrated into the final solution.

The upgrade to the vibration measurement system is intended to replace only the current measurement capability, not to add new functionality. This approach minimises the training burden on the operators, as there will be further changes with the full test cell upgrades to be implemented in the near future.

This report describes the test-cell upgrade in terms of the hardware and software installed in November 2003, and the testing of the system both in the laboratory prior to deployment, and installed in the test cells. A description of the software operation is found in Appendix B, while notes on each component of the software source code are included in Appendix C.

2. System Tests - Laboratory

2.1 Test Set-up

The complete system was subjected to testing in the Laboratory at DSTO Melbourne. The Endevco TFAS II system and control computer were connected in the same manner as in the final deployment in the Williamtown and Tindal METS. The only exceptions were that only one cable set and accelerometer were used for the tests, and the full scale range was set to 5.0ips[1] on all three vibration input channels.

[1] This is vibration amplitude measured in inches/second peak and is a parameter that is set during system configuration. In operation vibration amplitudes are displayed in inches/second average.

The accelerometer used for the test[2] was mounted back to back with a reference accelerometer[3] atop an electromagnetic shaker. The reference accelerometer was calibrated to a NATA (National Association of Testing Authorities) standard.

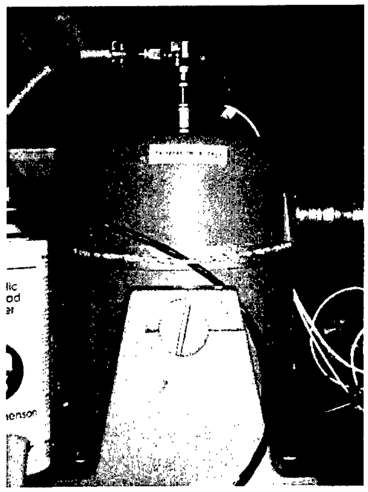


Figure 1: Shaker with test and standard accelerometers back to back.

The control computer/TFAS II system used in these tests at the DSTO Melbourne laboratory was the one installed in the engine run-up facility at RAAF base Tindal. The System installed at RAAF base Williamtown did not undergo this testing.

Each of the three vibration input channels was tested separately, with a sinusoidal input to the accelerometer of 3.0ips[4] average over a range of frequencies from 50Hz to 250Hz. This amplitude was chosen, as it is a significant fraction of the full-scale range of the system as deployed. The maximum frequency tested (250Hz) corresponds to approximately 90% on the high speed rotor in the F404 engine.

Figure 2 shows that the broadband response is attenuated with increasing frequency. At 250Hz the attenuation is 6 to 7% for the channels with the modified input filtering resistor (Section 5, while attenuation on the unmodified channel is less, only about 3% at 250Hz. Attenuation is expected due to the roll off characteristics of the low pass input filter, which are changed by the modifications described in section 5.

[2] Endevco 6222S-20A, Serial No. 15398

[3] PCB 301 A04, Serial No. 928

[4] The upper limit of the amplifier/shaker used.

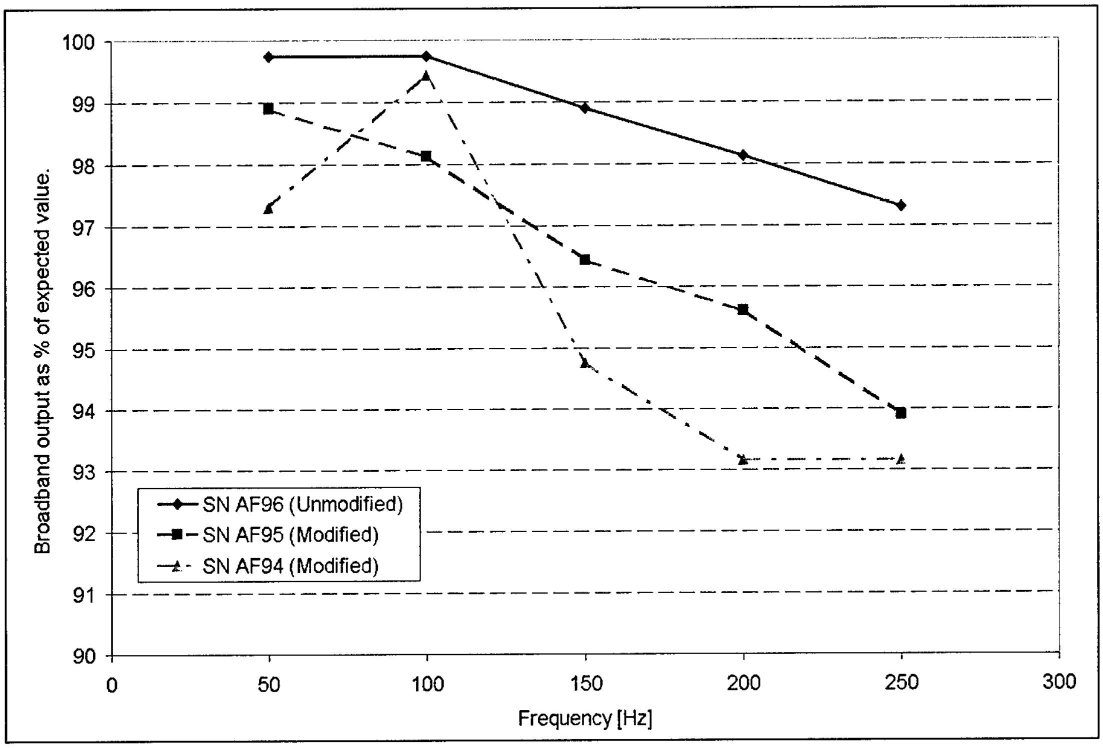


Figure 2: Broadband results by vibration channel.

2.2 Tracking Filter Tests

The operation of the tracking filters was tested at the same time as the broadband results from the vibration inputs. The output from the waveform generator that was used as input to the amplifier/shaker was also used as a tachometer signal for the tracking filters.

The shaker was driven with a sinusoidal input at a single frequency, with the tracking filters using the same signal to define their centre frequency. It is expected that the output from the tracking filters will match the broadband results. Tables 1 to 3 show this to be the case to within 2%.

2.3 Output to TFIA cards

The tracking filter cards require an input signal that is 1.0V peak at the full-scale value. The TFIA cards do not process the signal in any way, they are only to route the signal to the required tracking filter. This means that the output sent from the vibration amplifier boards must be 1.0V peak at the full-scale value. This parameter is a part of the set-up configuration.

For these tests, the full-scale range was set to 5.0ips peak on all of the vibration channels, thus 3.0ips average corresponds to an output of 940mV peak, or 665mV RMS. The attenuation discussed in Section 2 is reflected in the output to the TFIA cards. Comparison with the measured broadband values typically shows an agreement to within 1%.

2.4 Results Summary

Table 1: Results for 6647card #AF96 (Unmodified)

Amplitude [g PEAK]	Frequency [Hz]	Broadband [ips AVG.]	Tracked [ips AVG.]	TFIA Output [mV RMS]
3.83	50	2.992	2.988	673
7.67	100	2.992	2.915	669
11.50	150	2.967	2.903	663
15.33	200	2.944	2.891	661
19.17	250	2.919	2.867	660

Table 2: Results for 6647card #AF95 (Modified)

Amplitude [g PEAK]	Frequency [Hz]	Broadband [ips AVG.]	Tracked [ips AVG.]	TFIA Output [mV RMS]
3.83	50	2.967	2.963	666
7.67	100	2.944	2.939	659
11.50	150	2.893	2.891	651
15.33	200	2.868	2.830	640
19.17	250	2.817	2.806	633

Table 3: Results for 6647card #AF94 (Modified)

Amplitude [g PEAK]	Frequency [Hz]	Broadband [ips AVG.]	Tracked [ips AVG.]	TFIA Output [mV RMS]
3.83	50	2.919	2.951	655
7.67	100	2.983	2.927	648
11.50	150	2.843	2.879	637
15.33	200	2.795	2.806	629
19.17	250	2.795	2.806	624

3. System Tests - Engine Test Cells

At the deployment of the new system at each of the two test cells (Williamtown and Tindal) a comparison was conducted with the existing vibration measuring equipment. Results from these tests are presented in Appendix A.

3.1 Williamtown

A number of tests were conducted at Williamtown using engine number 058. For each test the engine was run at a number of power settings from ground idle to max. afterburner. At each setting, broadband measurements were recorded for the three transducer locations.

The first engine run was used to establish a set of baseline results using the original equipment. Two runs were then performed with readings taken at all three locations with the new equipment. These runs showed that the results from the mid-frame sensor, which is common between the two systems, were in close agreement (within ~10%). The front-frame measurements were typically about 40% less than with the original equipment, and the rear mount measurements around 20% lower. Two subsequent runs using the new equipment with the front and rear transducers swapped produced similar results. This behaviour indicates that the differences result from drift in the calibration of the original sensors. The original sensors were approaching the end of their calibration period, whereas the new transducers had recently undergone a NATA certified calibration.

Two final tests with changed filter settings[5] on the new equipment produced similar results. These tests rule out the possibility that low frequency signals, in the range from 20Hz to 70Hz, were affecting results from the existing system and not the upgraded system.

3.2 Tindal

The tests at Tindal were conducted using engine number 036. Three different runs were performed. For each test the engine was run at a number of power settings from ground idle to max. afterburner. At each setting, broadband measurements were recorded from each transducer.

The first run was to establish a baseline set of results using the existing equipment. The front frame and rear mount transducers were located on the bolt holes adjacent to their normal positions, as the new accelerometers had already been fitted. The vibration was still measured in a radial direction, and no significant difference is expected between this and the standard location. On the second run measurements were taken on all three channels using the new equipment. During this run, measurements were also

[5] The Low Cutoff (LC) was changed from 70Hz to 20Hz

taken simultaneously using the original equipment from the front and rear mount locations only. A final run was then performed after the original equipment had been completely removed.

Results from the testing at Tindal show similar behaviour to that at Williamtown. The mid-frame results are in close agreement, typically to within 10%. The results from the front-frame and rear mount locations are typically about 40% lower with the new equipment compared to the old. Again, the large differences between the two systems at the front-frame and rear mount locations are attributed to drift in the calibration of the original sensors.

4. Whole System Calibration

It is anticipated that the accelerometers used on the front-frame and the rear-mount will be calibrated separately from the rest of the system by Australian Defence Force Calibration (ADFCAL). This leaves the calibration of the TFAS II and control computer to be performed without the accelerometers attached. A portable accelerometer simulator, such as the Endevco model 4830A is ideally suited to this task. As the accelerometers are not required for this procedure all three channels, including the mid-frame where the accelerometer is permanently mounted on the engine, can be tested. This simulator has the following features that would be useful:

1. Differential charge type accelerometer simulation.
2. Variable frequency output (1 to 10kHz) covers required range (up to 1kHz).
3. Variable amplitude output (up to 10000pC peak)
4. TTL (0 to +5V) tachometer signal.
5. Portable.

It would be possible to check the operation of the tracking filters using the tachometer signal from this simulator. With a tachometer signal at the same (single) frequency as the simulated vibration input, the tracked level should read the same as the broadband measurement. Access would be required to the tachometer signal inputs at the back of the TFAS II rack to perform this test. In addition, it may be necessary to change the gain on the N2 tachometer channel to correctly read the TTL signal. The N1 channel is configured to an appropriate range for this signal.

If the system, using this test procedure, is found to be outside acceptable tolerances[6], the affected components should be replaced with spares. Rectification of the unserviceable equipment may be performed by the supplier.

[6] Tolerance limits for the Endevco recommended calibration sequence are listed on Page 3-44 of the Endevco instruction manual IM68220, Revision C, 5th September 1997.

5. Input Filtering

5.1 High Pass filtering

The software configured high pass filter is used to attenuate the response to low frequencies. This filter serves to both exclude noise, such as interference from electrical equipment, and low frequency engine shake, and reduce the overemphasis of low frequencies that occurs as a result of the integration to velocity. The filter characteristics are as follows:

- Four pole Butterworth (24dB/octave).
- Lower -5% corner frequency at 70Hz.

5.2 Low Pass filtering

There are two resistors on the input to the charge converter on the 6647 cards. The purpose of these resistors is to limit the high frequency response and prevent saturation of the charge converter by high frequencies. On both the front-frame and rear-mount channels, (marked as MODIFIED), the standard 100Ω resistors have been replaced by 9.1kΩ resistors. On the mid-frame channel the modified resistors are located within the wiring loom attached to the engine. Changing the resistors has the effect of altering the low frequency corner of the filter according to equation 5-1.

$$f_{CORNER} = \frac{1}{12.56 \times R \times C_P}$$

Equation 5-1

Where: R = Resistor value in ohms.
C_P = Accelerometer plus cable capacitance in pF.

As installed at Williamtown and Tindal, using the Endevco 6222S-20A accelerometer (2800pC) and approximately 75ft of 80pC/ft cable, the corner frequency is approximately 1kHz.

6. Conclusions and Recommendations

The new system as supplied has been calibrated by traceable NATA procedures. Where there are differences between the old and the new systems, the readings for the new system will take precedence. Further confidence in the new system is given by the close agreement between the readings obtained for the (common) mid-frame transducer. Further, it should be noted that the new system is of the type used to originally pass engines at the AGAETF/HdH facility at Melbourne, and used by GE(Lynn) for F404 development. It is recommended that the new system be accepted for operation.

It is recommended that a calibration of the system (excluding accelerometers) be performed using an accelerometer simulator, such as the Endevco 4830A. This test will provide further confirmation that the front frame and rear mount channels are performing to specification.

7. References

1. Endevco Instruction Manual - Signal Conditioning Amplifier System TFAS II. IM68220, Revision C, 5th September 1997.

Appendix A: Results From Installed Testing

A.1. Williamtown

BASELINE - Original Transducers (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.19	0.14	0.29	0.63	0.85	0.63	0.74
MID	0.16	0.15	0.30	0.31	0.31	0.42	0.48
REAR	0.28	0.20	0.37	0.66	0.68	0.75	0.99

NEW SYSTEM - 1st run (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.07	0.07	0.15	0.42	0.37	0.42	0.45
MID	0.10	0.04	0.30	0.30	0.34	0.34	0.45
REAR	0.37	0.22	0.35	0.57	0.60	0.70	0.82

NEW SYSTEM - 2nd run (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.12	0.07	0.12	0.37	0.35	0.40	0.42
MID	0.20	0.04	0.30	0.30	0.34	0.39	0.45
REAR	0.52	0.30	0.37	0.50	0.52	0.77	0.85

OLD SYSTEM - Front & Rear Tranducers Swapped							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.17	0.16	0.27	0.49	0.69	0.61	0.65
MID							
REAR	0.30	0.23	0.44	0.63	0.64	0.76	0.97

NEW SYSTEM - Swap Transducers; LC = 70Hz (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.12	0.10	0.12	0.37	0.30	0.42	0.42
MID	0.20	0.04	0.30	0.30	0.30	0.39	0.50
REAR	0.52	0.25	0.40	0.50	0.55	0.77	0.85

NEW SYSTEM - New Filter Settings; LC = 20Hz (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.07	0.07	0.17	0.40	0.37	0.47	0.45
MID	0.10	0.04	0.20	0.34	0.34	0.39	0.50
REAR	0.35	0.20	0.27	0.57	0.57	0.75	0.85

NEW SYSTEM - Final Run; LC = 70Hz (ips avg.)							
	GI	FI	13500	15000	15500	MIL	AB
FRONT	0.17	0.12	0.20	0.40	0.35	0.42	0.45
MID	0.10	0.10	0.39	0.25	0.30	0.39	0.45
REAR	0.42	0.50	0.35	0.52	0.52	0.75	0.82

A.2. Tindal

BASELINE - Original Transducers, mounted above New TX (ips avg.)								
	GI	FI	13500	14500	15000	15500	MIL	AB
FRONT	0.18	0.30	0.35	0.63	0.73		0.87	0.81
MID	0.31	0.19	0.23	0.26	0.31		0.49	0.47
REAR	0.31	0.50	0.51	0.65	0.87		0.60	1.35

NEW SYSTEM - TX in position (ips avg.)								
	GI	FI	13500	14500	15000	15500	MIL	AB
FRONT	0.10	0.10	0.22		0.47	0.50	0.55	0.52
MID	0.25	0.20	0.25		0.34	0.39	0.50	0.50
REAR	0.17	0.20	0.27		0.35	0.37	0.87	0.92

OLD TX – Simultanous (ips avg.)								
	GI	FI	13500	14500	15000	15500	MIL	AB
FRONT	0.19	0.24	0.38		0.74	0.90	0.85	0.83
MID								
REAR	0.37	0.33	0.51		0.80	0.75	1.20	1.35

NEW SYSTEM – Old equipment removed (ips avg.)								
	GI	FI	13500	14500	15000	15500	MIL	AB
FRONT	0.10	0.10	0.22	0.45	0.40	0.52	0.50	0.60
MID	0.30	0.20	0.25	0.25	0.34	0.34	0.50	0.55
REAR	0.15	0.17	0.30	0.32	0.37	0.40	0.75	0.85

Appendix B: METS_VIB Software Operation

B.1. Start-up Procedure

- Switch on the TFAS II rack and control computer.
- The TFAS II rack must be turned on before starting the METS_VIB program.
- If there is a problem with the self test at start-up check:
    a. That the TFAS II rack is switched on.
    b. That the GPIB cable from the control computer to the TFAS II rack is securely connected.
- If there is a problem with the cable test at start-up check that:
    a. The accelerometer cables are securely connected to the TFAS II rack.
    b. The connection in the accelerometer cables is secure.
    c. There is an accelerometer fitted.
- If there is a problem with the configuration:
    a. Ensure that all self-tests were passed.
    b. Reset the TFAS II rack using the reset option under the *Calibration and Self Test* menu – or;
    c. Restart the computer using the reset switch on the front, and switch the TFAS II rack off and then on again, making sure the rack has been restarted before starting the METS_VIB program again.
    d. If problem continues, check that the file *TFAS_Config.txt* is present in the program directory. <*C:\Program Files\Mets_vib*>

B.1.1 Launching the Software

The controlling software for the METS vibration system is started by selecting the icon, called METS_VIB as shown below, from the desktop. As stated, this should be done after the TFAS II rack has been turned on.

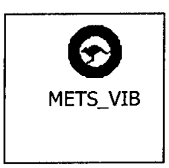


Figure 3: Program icon

B.1.2 Self Test

At start-up, there will be an option to run a system self test, though it may take up to several minutes this test is recommended. The test checks the functionality of the 2 model 6728M5 tracking filter cards, and the 3 model 6647 vibration amplifier boards. A

cable check is also performed on each 6647 board that verifies that an accelerometer is correctly connected, although the accelerometer itself is not tested.

Figure 2 shows a self-test in progress at start-up. Items selected for test are the 2 tracking filter cards in slots 1 and 2, and the 3 vibration amplifier boards in slots 5 through 7, these selections can not be changed. The Tracking Filter Input Assemblies (TFIA) in slots 9 through 11 will not respond to a self-test, and slots 8 and 12 are empty.[7]

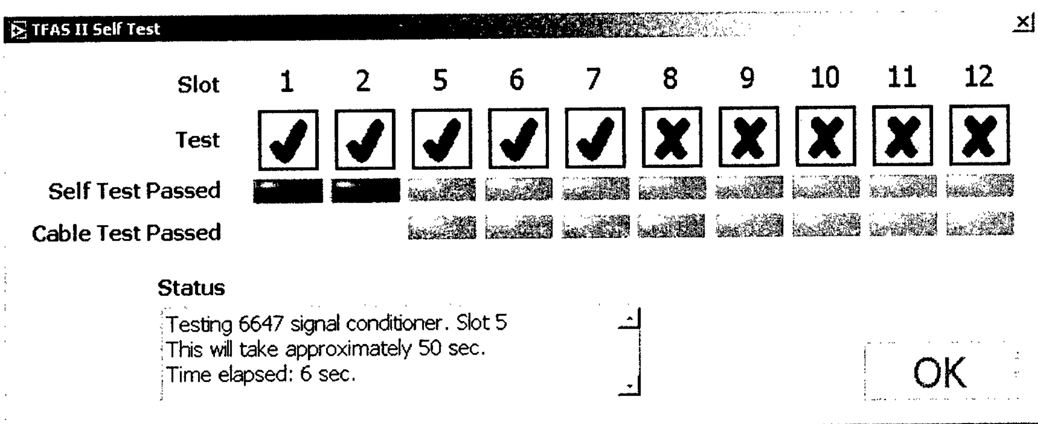


Figure 4: Self test at start-up

B.1.3 Configuration

After the self-test, the system is configured using parameters stored in a text file named *TFAS_Config.txt*. This file contains a set-up string for each tracking filter channel and vibration input channel, it must be located in the same directory as the METS_VIB software. A complete description of the possible set-up options may be found in the Endevco TFAS II instruction manual (IM 68220)

B.2. Main Screen

Access to the calibration and Self Test options are available through the option on this screen only when the data acquisition is stopped. Data acquisition will start when the GO button is pressed (it will change to STOP).

Displays are on the main screen for the following:

Overall vibration levels (front frame, mid-frame, rear mount)
Tracked N1 vibration levels (front frame, mid-frame, rear mount)
Tracked N2 vibration levels (mid-frame, rear mount)
N1 speed (RPM, %)

[7] Slots 3 and 4 are never used on the TFAS II system.

N2 speed (RPM, %)

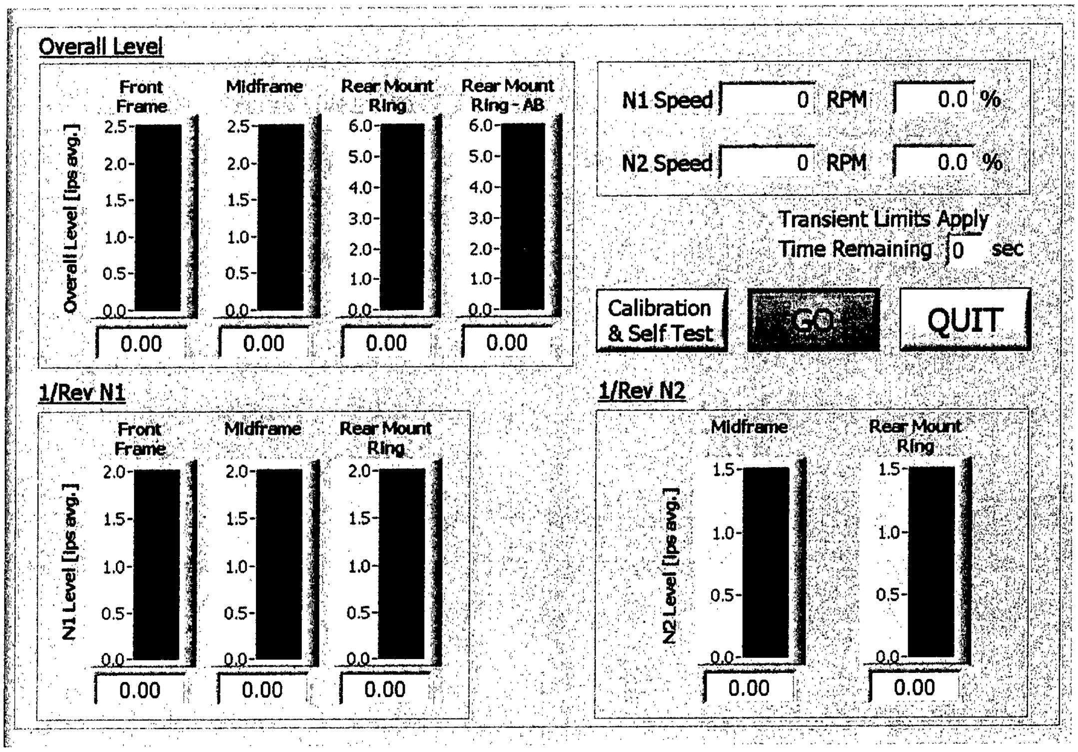


Figure 5: Main Screen

B.2.1 Vibration Limits

The vibration levels are shown as both a bar chart, with limits indicated by thick yellow lines, and as a numerical display.

Overall levels have both steady state limits and transient limits. When a limit is exceeded, the bar display and the numerical display turn red. In steady state conditions, this happens if the lower of the 2 limits (Yellow lines on charts) is exceeded.

In transient conditions, the higher limit is in force and exceeding the steady state limit won't trigger the alarm indication. Engine transients are detected by changes in the N2 speed and remain in force for 5 seconds after the transient (eg: throttle movement). A counter is displayed showing this 5 second countdown while the transient limit is applied.

Table 1[8] shows the limits applied at each of the 3 accelerometer locations for particular engine conditions.

Table 4: Engine Operating Limits

Location	Limit (ips average)
Front Frame	
1/rev N1, steady state	1.5
Overall, steady state	1.5
Overall, transient	2.0
Mid-frame (ECMS 4 o'clock)	
1/rev N1, steady state	1.0
1/rev N2, steady state	1.0
Overall, steady state	1.0
Overall, transient	2.0
Engine Rear Mount Ring[9]	
1/rev N1, steady state	1.0
1/rev N2, steady state	1.3
Overall, steady state	1.0*
Overall, transient	5.0

* The steady state limit for the overall vibration at the rear mount ring is raised to 1.5ips average during operation of the afterburner. A separate bar indicator, located next to the one for non-afterburner engine operations will indicate this limit. This additional indicator is used only during afterburner operation.

B.3. Calibration and Self Test

Selecting the Calibration and Self Test option brings up the dialog shown in Figure 4. The three functional options are Self Test, Internal Calibrate and Reset TFAS. The External Calibrate option is not yet implemented.

[8] Sourced from A1-F404A-MMI-200 (1 March 1993), 017 00 – Page 11.

[9] Limit for rear mount ring is increased by 0.5ips average during afterburner operation.

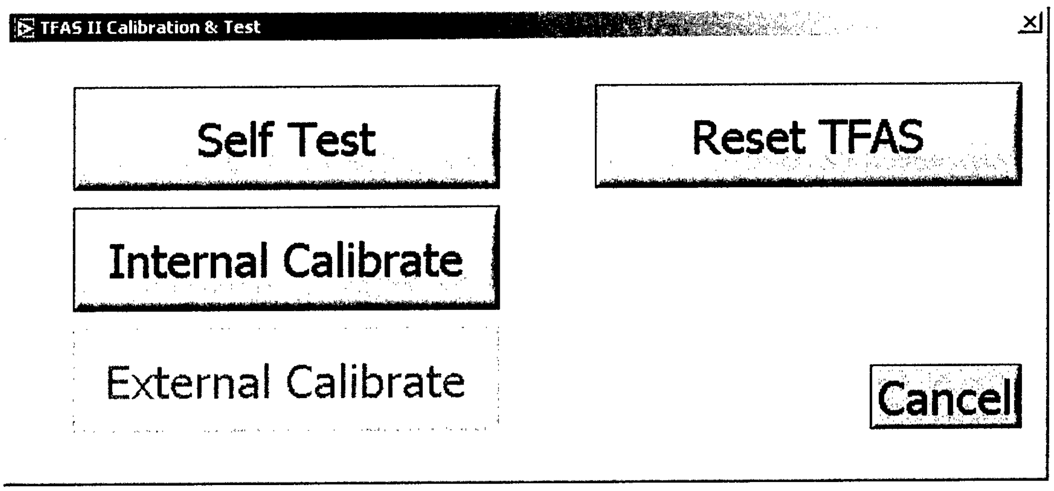


Figure 6: Calibration and Self Test Dialog

B.3.1 Self Test

The self-test dialog displayed here is the similar to the one shown at start-up, except that the user has the ability to select which slots/channels will be tested. A tick against a slot number will include it when the test is started by the GO button. As each component is tested, the indicator below it will light up green if successful and red if unsuccessful. At the completion of all tests, a summary will be displayed in the status window.

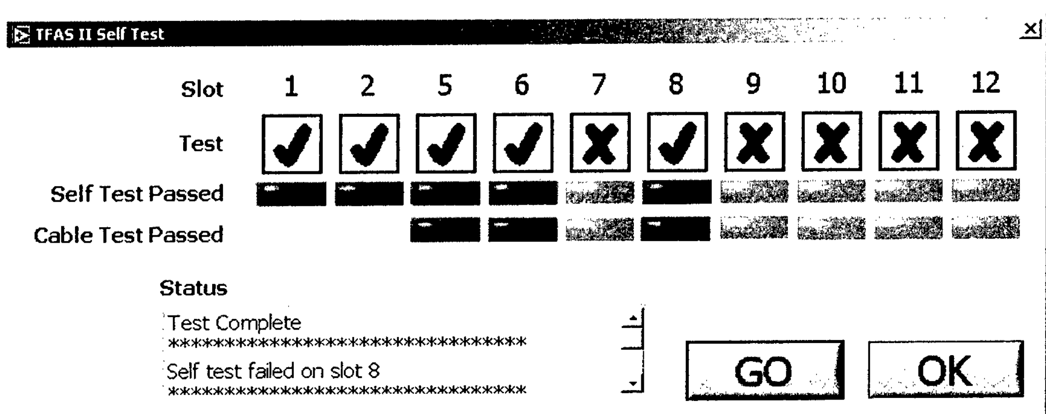


Figure 7: Example self-test dialog - test completed

In the F404 METS system, slots 5, 6 and 7 contain 6647 vibration amplifier boards which will respond to the self test command. A cable check will also be performed on each 6647 board that verifies that an accelerometer is correctly connected, although the accelerometer itself is not tested.

Slots 9, 10 and 11 contain TFIA cards that are used to route signals from the outputs of the vibration amplifiers to the tracking filter card in slot 2. The TFIA cards will not respond to a self-test command.

Once started, the test cannot be stopped before it is complete. Table 2 lists approximate times for the completion of a successful test.

Table 5: Component self-test times

Component test	Approximate time (sec)
6728M5 tracking filter card	10
6647 vibration amplifier	50
6647 cable test	5

B.3.2 Internal Calibrate

The internal calibrate function only applies to 6647 cards, these are channels 1, 2 and 3 in the F404 METS vibration system. The command enables a 100Hz oscillator at the input to the card, and the output compared to the desired value. The amplifier gain is adjusted to minimise the error. This process takes approximately 10 seconds per channel.

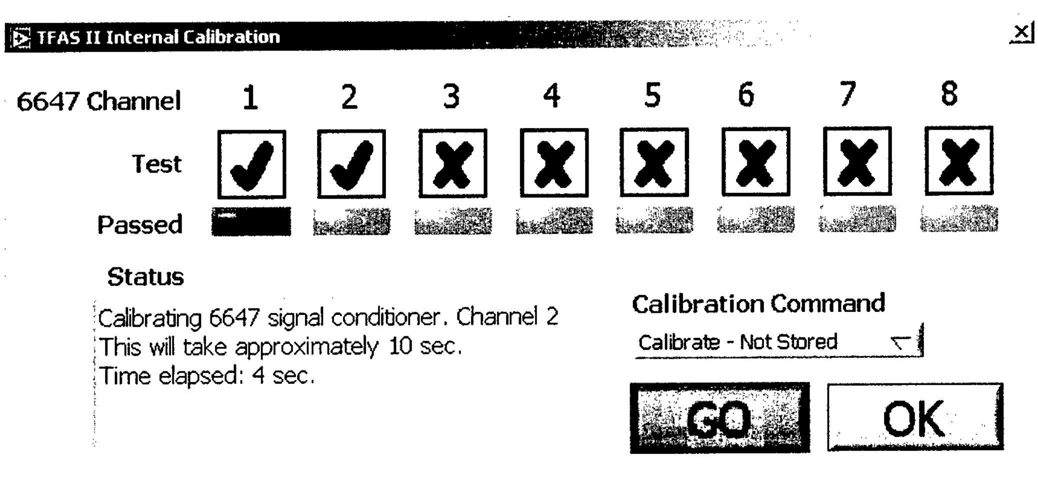


Figure 8: Internal calibrate function

A complete description of the internal calibrate function may be found in the Endevco instruction manual IM68220, Page 3-39.

B.3.3 Reset TFAS

The reset TFAS option is equivalent to switching off the system and restarting it. The TFAS II is reset, and then reconfigured from the settings stored in the file called *TFAS_Config.txt*. This file must be located in the same directory as the METS_VIB software.

Appendix C: Software Component Descriptions

The METS_VIB software is written using LabVIEW version 6.1. The source code is made up of a number of .vi files, each of which contains part of the code handling the flow of data or system set-up, and in some cases a component of the user interface.

This appendix contains a complete list of the .vi files with a brief description of their function. The accompanying CD has a copy of the source with annotations describing the important features.

C.1. Dialog_DSTO.vi

Hidden menu giving access to the following functions:

- Direct access to TFAS II configuration settings, allowing them to be modified or written out to a file.
- Ability to send any command directly to TFAS II.
- FFT and frequency sweep function.

C.2. Dialog_Error.vi

Generic dialog for displaying error messages. Available options may include Quit and Reset TFAS. The default option is OK, which will exit the dialog with no further action.

C.3. Dialog_external.vi

Dialog for switching a vibration input into the external calibrate mode. This option is not activated in the November 2003 release.

C.4. Dialog_internal.vi

Dialog for initiating an internal calibration of any 6647 channels present, and also allows the restoration of any stored calibration parameters.

C.5. Dialog_Message.vi

Generic dialog for displaying messages, no necessarily errors to the user. Available options may include Quit. The default option is OK, which will exit the dialog with no further action.

C.6. Dialog_selftest.vi

Dialog used to initiate self-test on the tracking filters, vibration inputs and associated cables and accelerometers. When run automatically on start-up this will perform the internal self-test on the 2 tracking filter boards, and the 3 vibration inputs. The cable test to verify the correct connection of accelerometers is also performed on the three inputs. When run manually any time after start-up this dialog may be used to select any particular card to perform the test on.

The ticks/crosses indicate which slots will be tested or not. The indicators below show whether or not the test has been passed.

C.7. Dialog_SkipTest.vi

This dialog appears at start-up to enable the self-test to be skipped. It is recommended that the self-test be performed each time the system is started.

C.8. Dialog_SweepFFT.vi

Dialog that allows the frequency sweep/FFT settings to be changed, and these two functions to be performed. Output is to an on-screen chart, the current level on the selected channel is displayed in a bar to the right, all output is in ips peak. Frequency units may be switched between Hz and CPM.

This dialog is hidden, access is only via the Dialog_DSTO.vi menu.

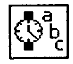
C.9. Dialog_testcal.vi

Dialog that allows the user to manually initiate a self-test, internal calibration or TFAS reset. The external calibration option is not implemented in the November 2003 release.

C.10. Dialog_TFAS_Configure.vi

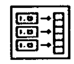
This dialog shows the status of the TFAS configuration process. On start-up the configuration variables are read into each TFAS card from a file. The file is called "TFAS_Config.txt" and must be located in the same directory as the main program METS_VIB.exe.

C.11. ElapsedTimeString.vi



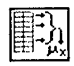
Returns the difference in time between some previous value and now in seconds. The previous time input value is measured as the number of seconds that have elapsed since 1 January, 1904 (LabVIEW function Get Date/Time In Seconds), the output value is a string.

C.12. GetBarData.vi



Combines the data for alarm levels and the actual value to be displayed on the chart and outputs an array containing both. Since the plots used are graphs and not bar charts, arbitrary X coordinates are used to create the effect of a bar using an ordinary graph.

C.13. GetMeanFrequency.vi

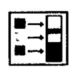


Strips the frequency information out of the data array that is returned from TFAS and takes an average. This is done to increase the refresh rate of the rotor speeds as an update is performed each time a tracked vibration measurement is taken.

C.14. METS_VIB.vi

This is the controlling vi for the entire program, it is at the top of the software component hierarchy. On start-up it calls the procedures for self-test and configuration of the TFAS. This vi controls the actions performed when any of the buttons on the main screen are pressed, and what data is collected from TFAS and displayed when running.

C.15. Set3ColourBar.vi

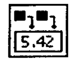


This vi sets the colours on a bar chart. Given the current display value, and the applied limits, the chart colour is selected from an input array of colours. The limits are always plotted first and are coloured yellow.

C.16. SetBOOL.vi

Sets the enabled state and value of a boolean indicator.

C.17. SetDisplayColour.vi



This vi sets the colours of an indicator display. Given the current display value, and the applied limits, the display colours are selected from two input arrays of colours, one for the text, another for the background.

C.18. SetMetsDisplay.vi

This vi takes the array of current data (Including the limits and links to the appropriate displays on the main screen.) and sets the values on those displays. The colour arrays for the bar charts and numeric indicators are kept here. The appropriate colour array to use is selected according to the transient flag - a separate array is used for the transient condition. This vi makes calls to GetBarData.vi, Set3ColourBar.vi and SetDisplayColour.vi.

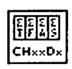
C.19. TFAS_6647config.vi

One of the hidden screens, accessible only from the DSTO menu screen. This screen displays the configuration settings for any of the vibration input channels, and allows them to be modified.

C.20. TFAS_6728M5config.vi

One of the hidden screens, accessible only from the DSTO menu screen. This screen displays the configuration settings for any of the tracking filter channels, and allows them to be modified.

C.21. TFAS_ChannelDataRequest.vi

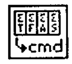


Splits a TFAS data request command into its component parts. For example, is it a vibration channel command, or a tracking filter command, and which channel does it refer to?

C.22. TFAS_CLRSRQ.vi

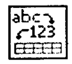
Clears the SRQ (control) line on the TFAS by repeatedly polling TFAS and checking the output against a list of possible values. Will stop either when there has been an error, or the control line is clear and the TFAS is idle.

C.23. TFAS_cmd.vi



This is a dialog that is accessible only from the hidden DSTO menu. It allows commands to be sent directly to the TFAS, and it enables the TFAS to be manually polled for messages on its control line.

C.24. TFAS_FormatData.vi



Given an output data string from TFAS II, such as those returned by TFAS_GetData.vi, this function produces a 3D numeric output array. Each page contains the data from a data request command. Broadband measurements are converted into units of ips average.

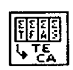
C.25. TFAS_GetData.vi

Given an array of TFAS data request commands, this function will process each request and return an array of strings containing the measured data. A second output array indicates the success of each call with a boolean flag.

C.26. TFAS_OK.vi

Given a decimal TFAS serial poll message value, this vi will return a string with the message description and a boolean flag indicating whether or not an error has occurred. Information in this vi is sourced from page 3-13 of the Endevco instruction manual IM68220, revision C, 5th September 1997.

C.27. TFAS_selftest_cal.vi

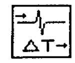


This vi sends self test or calibration commands to TFAS. The commands are input as an array of structures that contain; a flag indicating if this command is active, the command text, the text for the status indicator, a reference to an indicator to show success or failure, and the slot number. The status string is updated with the time elapsed while TFAS is processing the request.

C.28. TFAS_SRQMSG.vi

Polls TFAS and returns a string with the serial poll message, and a boolean flag indicating whether or not an error has occurred.

C.29. Transient.vi



By examining an array that keeps a history of the N2 spool speed, this vi determines whether or not the engine is currently in transient conditions. Transient conditions are defined as when the throttle is moved, and for 5 seconds thereafter. Throttle movement is inferred from changes in the N2 rotor speed.

C.30. Software Component Hierarchy

The links between each of the software components previously described are shown in Figure 9. A red line from the bottom of one icon links it with another component that it calls.

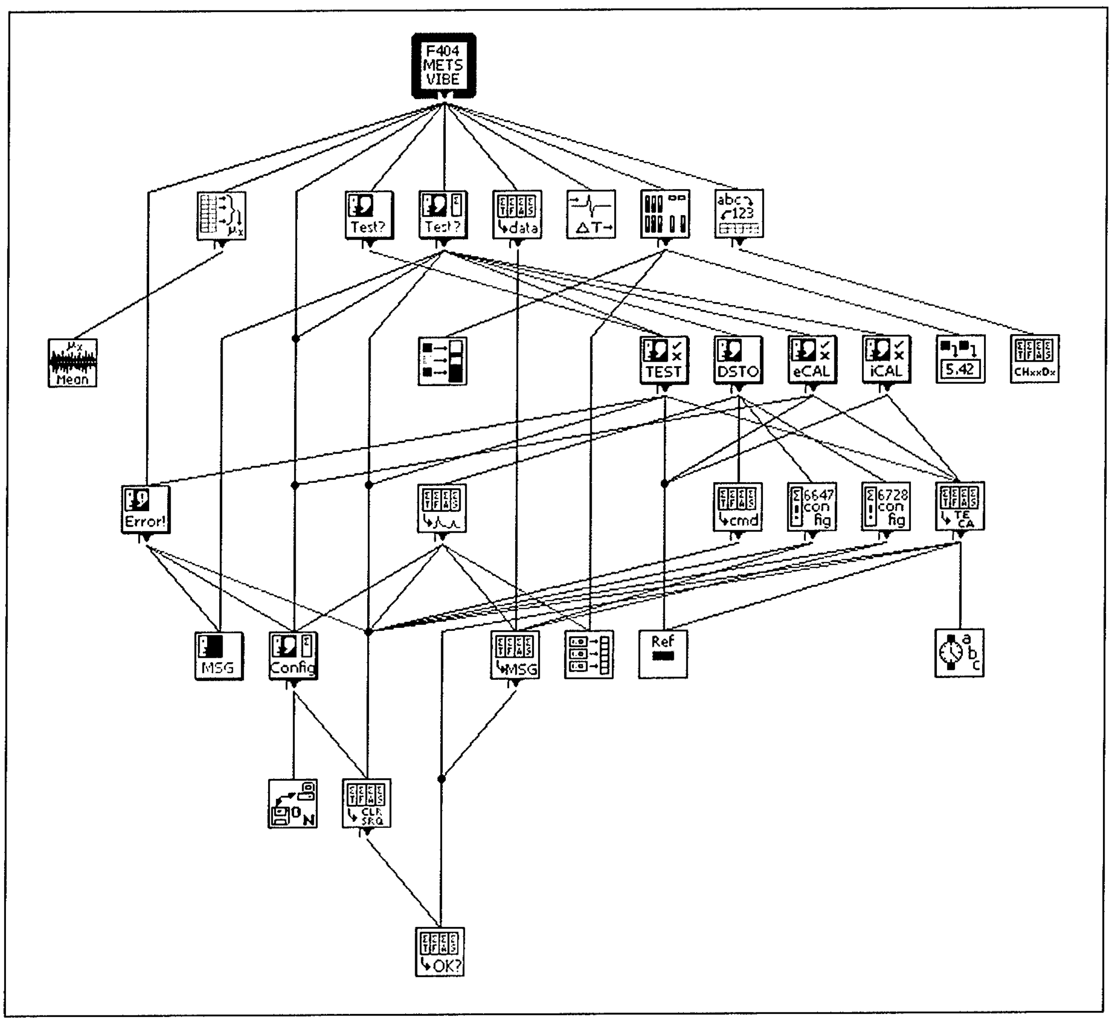


Figure 9: Software component hierarchy

Appendix D: Hardware Components Listing

The following is a list of the components for each system.

Component	QTY
TFAS II System - 68222 (Endevco)	
4970 19" rack	1
26752-9 Digital controller	1
6728M5 Tracking filter card	2
6647 vibration amplifier board (2 with 9.1kΩ resistor mod.)	3
27865 Tracking Filter Input Assembly (TFIA)	3
Accelerometers (Endevco)	
6222S-20A (with 3 x 8/32 UNC mounting screws)	2
Cables	
Type 5150 Endevco 2793-2 GPIB cable (2m)	1
Type 6917B-500 (Actual 640) DIN-MS	
Terminated with DIN cable mounting male plug (screw lock)	2
Type 6960-500	
Terminated with DIN cable mounting male plug (screw lock)	
Terminated with BF8-1212-12SV-Y7O connector	1
Type 6960-400	
Terminated with DIN cable mounting female socket	
Terminated with 9 pin plug EJ724	4
15 pin D-type plug to BNC	3
Tachometer splitter	
MS3101E-10SL-3P to MS3106E-10SL-3S plus 3 pin XLR socket	2
Tachometer extension	
3 pin XLR to BNC, length = 4.5m	2
Control computer	
Industrial motherboard chassis with 400W P4 ATX power supply	1
Gigabyte MicroATX P4 motherboard	1
Pentium 4 2.4GHz CPU	1
512MB PC2100 DDR RAM	1
40 GB 7200RPM Hard drive	2
CDRW	1
Windows 2000 Operating System	1
PCI bus GPIB board	1
3m VGA cable	1
15" LCD resistive touch screen monitor, panel mount.	1

Appendix E: Description of Tachometer Cable Splitters

E.1. N1 and N2 Tachometer Splitter

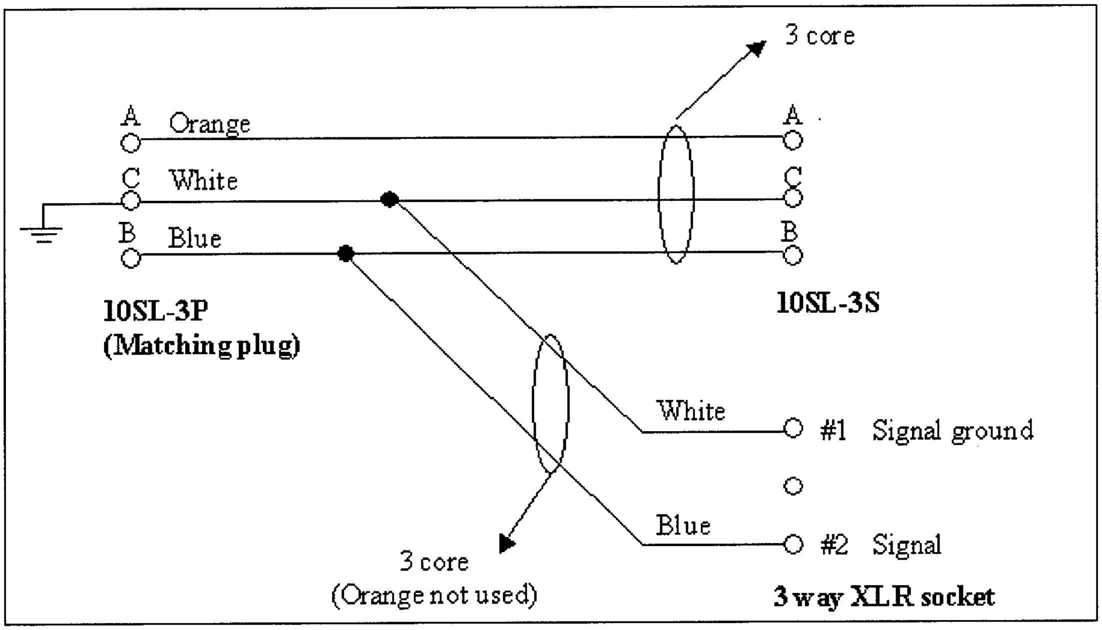


Figure 10: N1 and N2 Tachometer Splitter Cable

E.2. Cable to TFAS II Rack

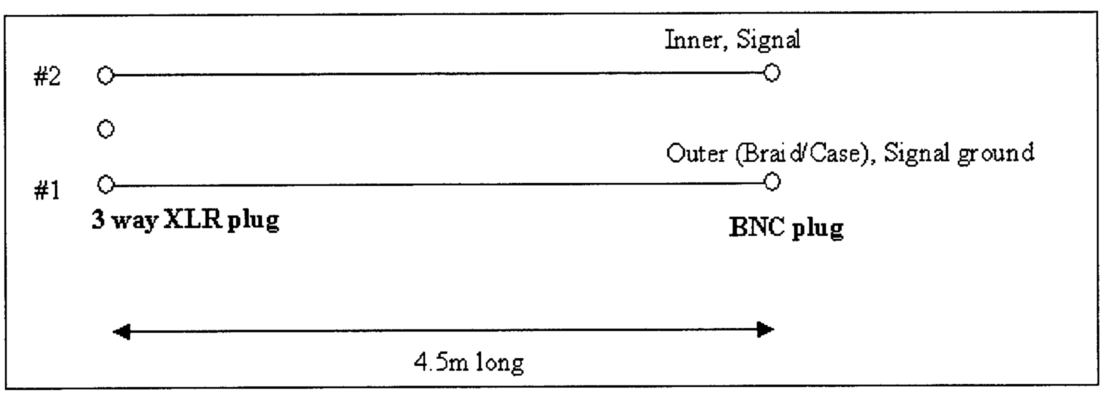


Figure 11: Tachometer cable for connection to TFAS II rack

Appendix F: Description of Connecting Cable From 6647 Vibration Amplifier Board to 27685 TFIA Card

- 70 Ohm coaxial cable
- 15 pin D-type connector to BNC
- Pins #3 (AC output) and #10 (GND) are connected on the 6647 card output (See Figure 13).
- Length is approximately 40cm.

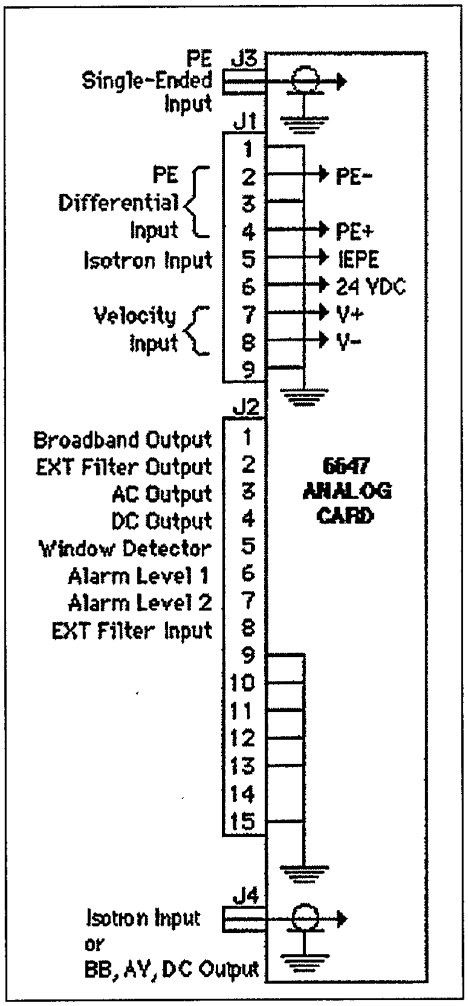


Figure 12: Wiring diagrams for back panel connections

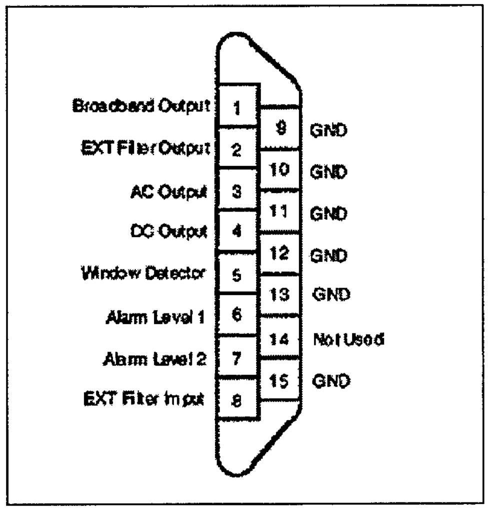


Figure 13: Analog card output connector.

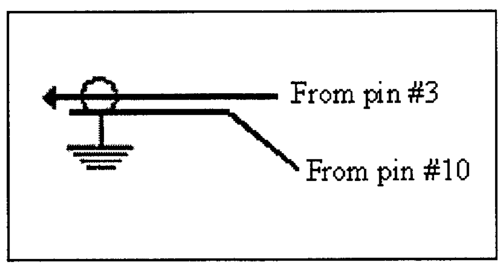


Figure 14: BNC connector for input to TFIA

Appendix G: Tracking Filter Input Assembly (TFIA) Card Modifications

In order to work correctly with the TFAS II system, a 27865 TFIA card requires a trace on the non-component side of the board. The trace is designated CD7, and must be cut in the location shown in Figure 15 below.

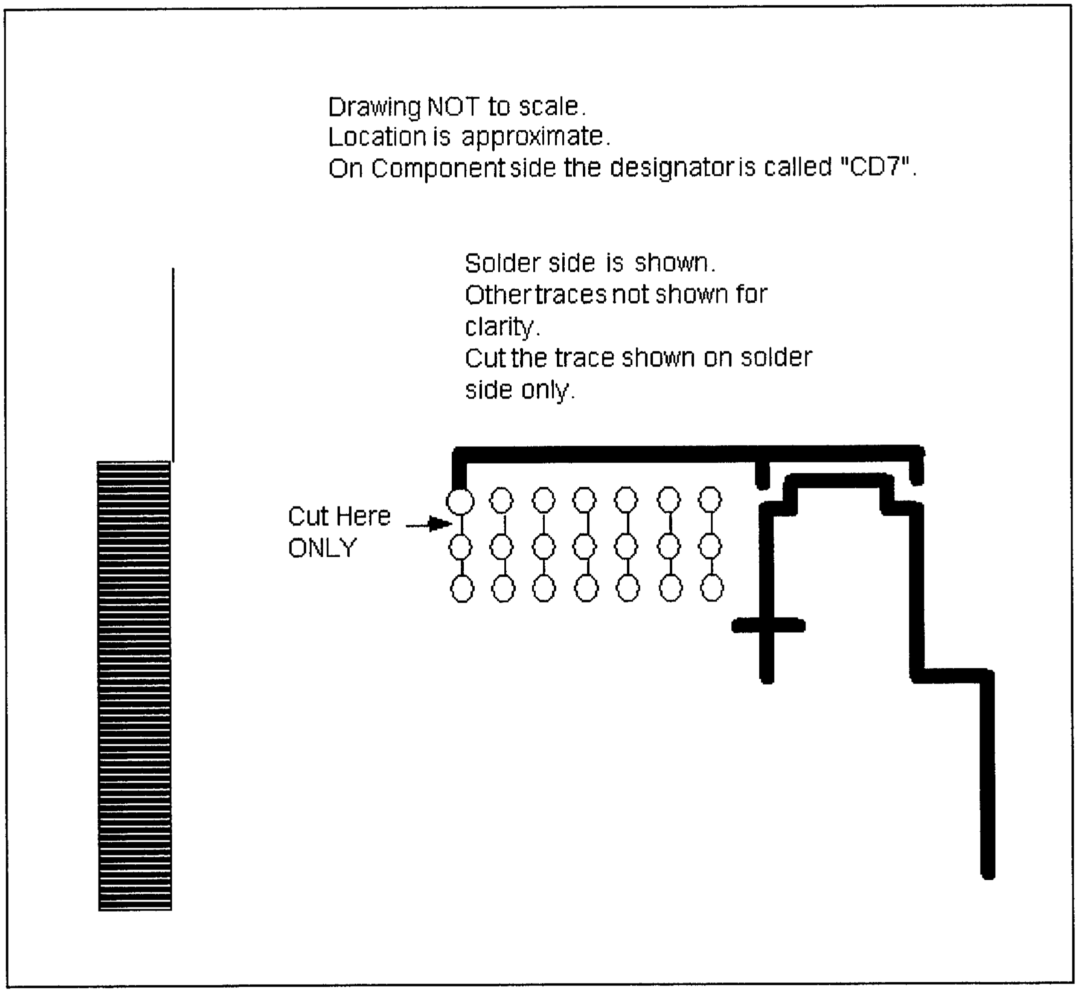


Figure 15: TFIA trace modifiaction

Appendix H: 6647 Vibration Amplifier Board Modifications

There are two resistors on the input to the charge converter on the 6647 cards that may be modified to alter the high frequency response. To limit the high frequency response, all three vibration channels in the F404 METS TFAS II system have been modified. Two of the channels, the front frame and the rear mount ring have the modified resistors on the 6647 card, the mid-frame channel carries the modified resistors in the wiring loom external to the card.

The modified channels are labelled on the outside of the 6647 card, and on the internal shielding, as shown in figures 16 and 17.

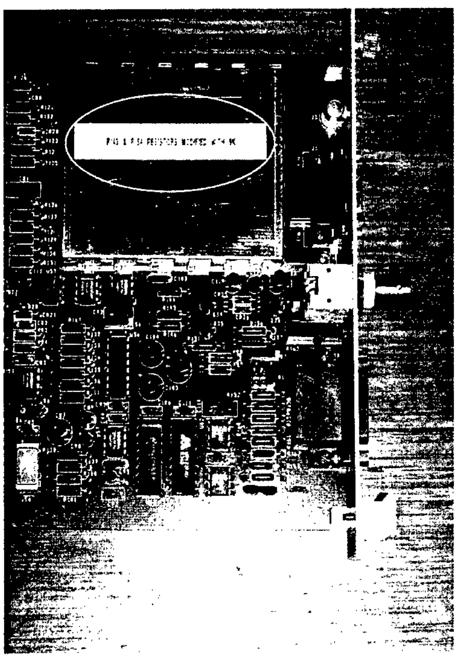


Figure 16: 6647 filter resistor modification (circled)

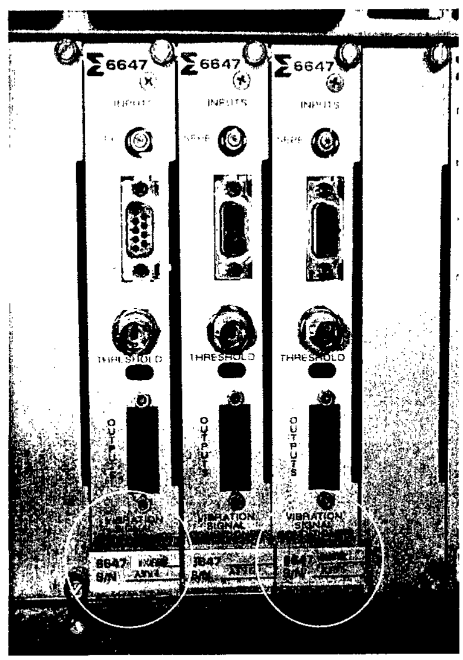


Figure 17: 6647 modification labels (circled)

The modified resistors have a value of 9.1kΩ. With the 6222S-20A accelerometer (2800pF) and 75ft of 80pF/ft cable, the -3dB corner frequency of this input filter is approximately 1.0kHz.

A complete description of the input filtering on the 6647 cards may be found in Endevco instruction manual IM68220, page A-3.

Appendix I: . Test Points for Whole System Calibration

The Endevco model 4830A accelerometer simulator is capable of producing a simulated signal over a range of frequencies and amplitudes. For the calibration of the TFAS system, it is suggested that two frequencies be tested; 100Hz, the frequency referenced in the calibration of the accelerometers, and 280Hz, corresponding to the 100% N2 rotor speed.

The tables below give the vibration amplitude settings in pC that correspond to various levels in ips average, as would be measured by the TFAS system. A range of values is listed appropriate to each channel.

Table 6: Front frame accelerometer calibration points

Front Frame (Sensitivity: 20 pC/g)				
	100Hz		**100% N2 = 280Hz**	
ips avg	**g PK**	**pC**	**g PK**	**pC**
0.5	1.28	26	3.58	72
1.0	2.56	51	7.16	143
1.5	3.83	77	10.73	215
2.0	5.11	102	14.31	286
2.5	6.39	128	17.89	358

Table 7: Mid frame accelerometer calibration points

Mid Frame (Sensitivity: 50 pC/g)				
	100Hz		**100% N2 = 280Hz**	
ips avg	**g PK**	**pC**	**g PK**	**pC**
0.5	1.28	64	3.58	179
1.0	2.56	128	7.16	358
1.5	3.83	192	10.73	537
2.0	5.11	256	14.31	716
2.5	6.39	319	17.89	894

Table 8: Rear mount accelerometer calibration points

Rear Mount (Sensitivity: 20 pC/g)				
	100Hz		**100% N2 = 280Hz**	
ips avg	**g PK**	**pC**	**g PK**	**pC**
1.0	2.56	51	7.16	143
2.0	5.11	102	14.31	286
3.0	7.67	153	21.47	429
4.0	10.22	204	28.62	572
5.0	12.78	256	35.78	716
6.0	15.33	307	42.93	859

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Validation of an Upgraded Vibration Measurement System for RAAF F404 Engine Test Cells	Document (U) Title (U) Abstract (U)

4. AUTHOR(S)	5. CORPORATE AUTHOR
P.R. Marsden	Platforms Sciences Laboratory 506 Lorimer St Fishermans Bend Victoria 3207 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TN-0530	AR-012-991	Technical Note	December 2003

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
2003/743958	AIR 03/ 189	DGTA	35	1

13. URL on the World Wide Web	14. RELEASE AUTHORITY
http://www.dsto.defence.gov.au/corporate/reports/DSTO-TN-0530.pdf	Chief, Air Vehicles Division

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19. ABSTRACT

Ground testing of the F404 engines of the F/A-18 Hornet at RAAF Williamtown and Tindal, essential to the continued safe operation of the aircraft, has been limited in its effectiveness by outdated test equipment. An upgraded vibration measurement system purchased by TFSPO will enable both test stands to to reliably and effectively implement the engine work package procedures, and identify faults. This report details the integration of the hardware components, and the testing and calibration of the system pre and post installation. Laboratory tests and installed comparisons with the existing system indicate that the new equipment is functioning correctly.